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TECHNICAL REPORT 8803

COMPARISON OF PARTICULATE LEAD LEVELS FOR DIFFERENT AMMUNITION TYPES USED WITH THE M16 RIFLE

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Airborne lead generated during firing of convential ammunition has lead to health concerns at indoor firing ranges. This study compares the relative amounts of airborne lead produced by the M16 rifle firing the M193 standard M16 5.56-mm conventional ammunition, the M862 5.56-mm plastic training ammunition, and the conventional caliber .22 rifle cartridge. Both breech and breech plus muzzle lead emissions were determined for each type of ammunition.

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INTRODUCTION

Recent industrial hygiene evaluations of Army National Guard indoor firing ranges have led to the closing or limited use of about 2/3 of the approximately 1,600 existing ranges.[1] The closings are due to lead and lead oxide contamination that resulted from poor ventilation systems that were unable to effectively remove the airborne lead generated during firing of conventional ammunition. While unsafe lead concentrations do not pose an immediate health threat, accumulation of this heavy metal in the body can degrade organ function and can be toxic to the nervous system.[2, 3, 4]

As a result of these evaluations, the question has been posed as to what effects various ammunition types have on the concentration of airborne lead. The caliber .22 rifle cartridge is the most common ammunition in use for National Guard training in indoor ranges; it is fired from an M16 rifle fitted with a .22 caliber subcaliber device adaptive bolt and an appropriate magazine. The National Guard Bureau has proposed the alternative of using the new M862 5.56-mm plastic training ammunition in indoor ranges as a means of reducing airborne lead concentrations. The only source of lead in the plastic round is from lead styphnate in the primer. The United States Army Biomedical Research and Development Laboratory has been asked by the National Guard Bureau to evaluate potential lead-related health hazards from the new ammunition in indoor ranges.[5] For the sake of completeness, a comparison has been conducted of all three types of ammunition currently used with the M16 rifle: the M193 standard M16 5.56-mm conventional ammunition (hereafter referred to as standard or metallic rounds); the M862 5.56-mm plastic training ammunition (hereafter referred to as plastic or non-metallic rounds); and the conventional caliber .22 rifle cartridge (hereafter referred to as .22 rounds). Of main concern to this study are the plastic and .22 rounds.

The M16 rifle was fired within a metal housing designed to contain total gaseous and aerosol emissions. For each of the three types of ammunition, we sampled total emissions and emissions from the breech end only. These samples were analyzed for lead by atomic absorption (AA) spectroscopy.

The weapon was fired and the emissions sampled at the COL James Bartgis Rifle Range near Linganore Road in Frederick County, MD; this range is operated by the Cresap Rifle Club of Middletown, MD.

EXPERIMENTAL

MATERIALS

We obtained the standard rounds from the U.S. Army Garrison, Ft. Detrick, MD; .22 and plastic rounds were supplied by the National Guard Bureau. In order to fire other than standard rounds, special adaptive bolts or devices are necessary. We obtained a .22 caliber subcaliber device and an appropriate magazine from the National Guard Bureau for .22 rounds. An XM2 5.56-mm automatic weapon practice bolt from the same source was used to fire the plastic rounds.

The all-metal test housing, referred to above, had a teflon-coated interior (Figure 1). It consisted of two sections, muzzle and breech, each with an endplate. The sections were bolted together to give a total volume of 133 L. The endplates were bolted on in the same manner. Around the edges of these connections were large rubber o-rings to make the housing nearly air-

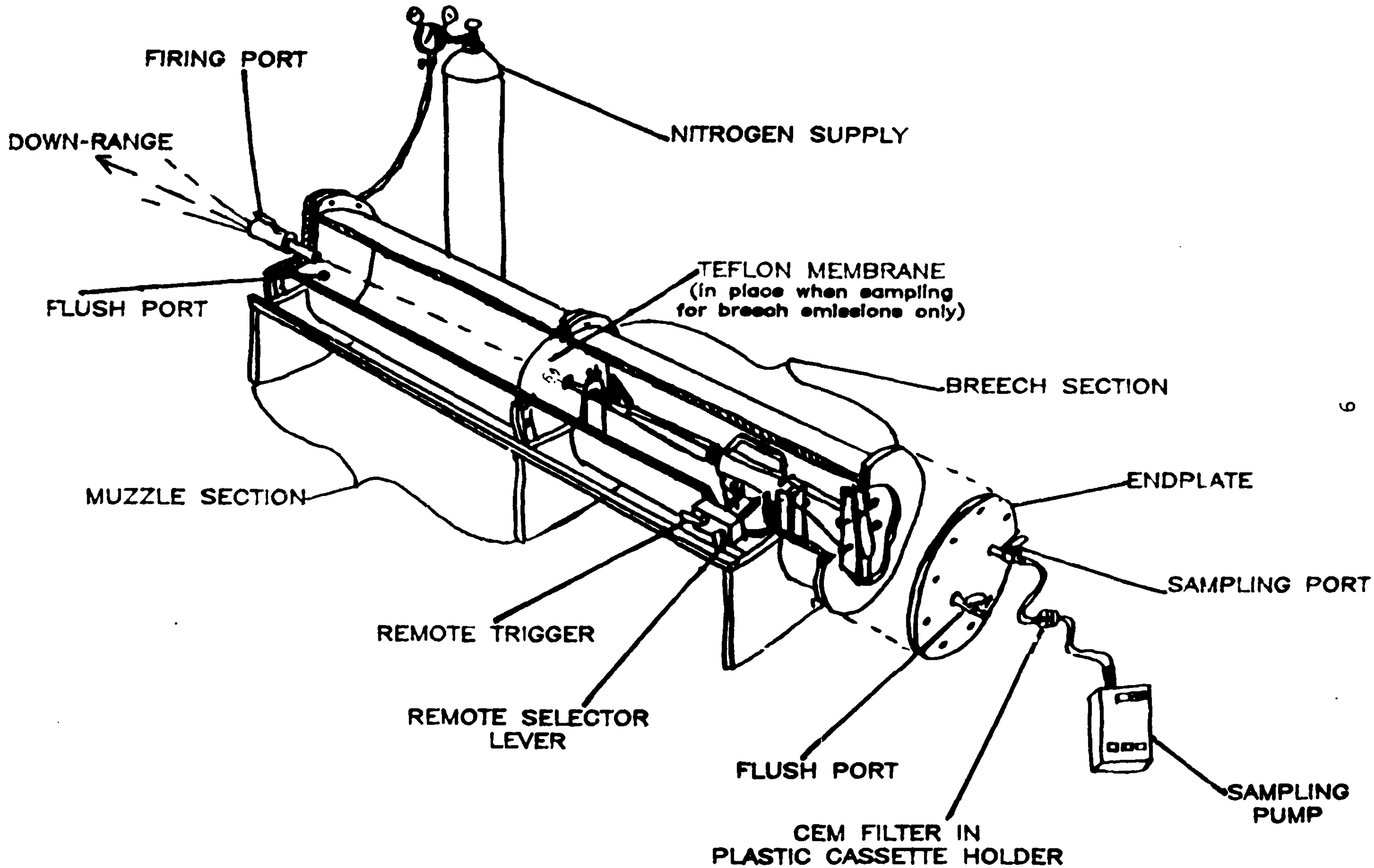

FIG. 1. M16 in TEST HOUSING

tight, so that it would totally contain the gaseous and aerosol emissions of a weapon fired within it. The breech section of the housing featured remote trigger and remote safety selector lever mechanisms that permitted operation from the outside. The muzzle endplate of the housing had two valved ports: a firing port and a flushing port. During firing, the firing port was opened to allow the fired round to escape downrange. During sampling, the firing port was closed and the flushing port was opened to permit equalization of pressure. The latter port was also used to flush the housing with nitrogen between samplings. The breech endplate of the housing also had two ports: a sampling port through which the sample was drawn, and a second flushing port used for sampling breech emissions.

A teflon membrane (thickness of 0.065 in) was used to modify this housing for breech emissions sampling. This membrane acted as an endplate, replaced the muzzle section of the housing, and fit around the flash suppressor of the M16 rifle, allowing muzzle emissions to escape, but trapping breech emissions within the housing. This arrangement made use of only one section of the housing and its total volume was 66.5 L. The flushing port on the breech endplate was opened while breech emissions were being collected, both during sampling to permit equalization of pressure, and while the housing was being flushed with nitrogen between samplings.

This entire test housing was mounted on a 4 ft x 8 ft trailer for ease of transport to the firing range.

Particulate samples were taken with an Alpha 1 Air Sampler (E.I. du Pont de Nemours and Co., Wilmington, DE) that drew air from the housing through a 37 mm dia. 0.8 μm cellulose ester membrane (CEM) filter (Gilian Instrument Corp., Wayne, NJ).

Pressurized nitrogen (oil free, 99.5%) was used to flush the housing between samplings.

The flow rate of the sampling pump was set and checked with a Gilibrator primary air flow measuring device (Gilian Instrument Corp., Wayne, NJ).

Samples were analyzed for total lead by AA spectroscopy. All analyses were performed on a Perkin-Elmer (Norwalk, CT) model 3030 atomic absorption spectrophotometer equipped with a Perkin-Elmer model 057-0761 electrodeless discharge lamp (EDL) power supply and a model PR-100 printer. An air-acetylene flame was used throughout the study with the spectrophotometer wavelength set at 217 nm.[6] Analytical standards for lead were prepared from Fisher Scientific Company (Fair Lawn, NJ) 1000-ppm certified atomic absorption reference solution. Prior to analysis, the samples were digested with concentrated nitric acid (Baker Ultrex) and 30% hydrogen peroxide (Baker Analyzed Reagent; A.C.S. Grade). Both digestion chemicals were obtained from J.T. Baker Chemical Company (Phillipsburg, NJ).

PROCEDURE

For total emissions sampling, one round of each type of ammunition was fired. For breech emissions sampling, nine rounds of each were fired. The M16 and the test housing were handled and operated in accordance with an in-house safety test procedure.

The weapon was secured in the housing during firing. The trailer carrying the housing was positioned so as to point downrange. The breech endplate of the housing had to be removed, and the two sections of the housing detached, to permit the weapon mounting. When the weapon had been secured at both the breech and muzzle ends within the housing, it was placed on 'SAFE' and loaded with the appropriate magazine. The two sections of the housing were then reconnected and the endplate replaced.

The firing port was opened to allow the fired round to escape downrange. The weapon was operated with the remote selector lever and the remote trigger. After the round had been fired, the firing port was closed and the sampling and flushing ports opened. The procedure used when firing for breech emissions was similar to that used for total emissions, but the two sections of the housing were left detached and the teflon membrane was fitted around the muzzle of the weapon, covering that end of the housing. This allowed emissions from the muzzle to escape while breech emissions were being trapped inside the housing. The breech endplate of the housing was replaced as usual. The sampling and flushing ports were closed during firing and opened during sampling.

Sampling was conducted at 3 L/min for 10 min, to give a total sampled volume of 30 L.

Between samplings the housing was flushed with nitrogen. When total emissions were being sampled (both sections of the housing being used), the housing was flushed at 66 L/min for 10 min. More than 99% of the residual combustion products were removed by this procedure (see Appendix A for calculations). When breech emissions were being sampled, with use of the teflon membrane and only one section of the housing, the effective volume was half the volume of the total housing; for this operation, the housing was flushed at 66 L/min for 5 min. Blank particulate samples were obtained to verify completeness of flushing.

When the same type of ammunition was reloaded, only the breech endplate was removed, so it was necessary to flush the housing with nitrogen. However, when we switched from one ammunition type to another, no flushing was necessary, because we detached the sections of the housing and removed the breech endplate in order to take the rifle out, change bolts and re-load. In this case, the housing was left open to flush naturally with air for at least 15-20 min. Again, blank particulate samples were obtained to verify efficiency of flushing.

The cassette filter holders were brought to the laboratory intact; there they were opened and the filters transferred to 150-mL glass beakers. Prior to analyses the CEM filters were prepared by the acid-hydrogen peroxide digestion method outlined in NIOSH method 7082 for analysis of samples for lead.[7] Three mL of concentrated nitric acid (HNO_3) and 1 mL of 30% hydrogen peroxide (H_2O_2) were added to each beaker. The beaker was heated on a hotplate at 140°C until most of the acid had evaporated. This step was repeated two more times with 2 mL of HNO_3 and 1 mL of H_2O_2. The sample was heated to dryness and the sides of the beaker were rinsed with 3 to 5 mL of 10% HNO_3; the sample was again heated to dryness. The beaker was allowed to cool and 1 mL of concentrated HNO_3 was added. The sample was then quantitatively transferred to a 10-mL volumetric flask and diluted to volume with distilled water. The solution was then analyzed by AA by direct aspiration without any further dilution. All glassware was cleaned in concentrated HNO_3 and rinsed in distilled/deionized water before use.

RESULTS and DISCUSSION

Table 1 shows the results in mg/filter for the sampling of total lead

(Pb) emissions. One round was fired and one filter used for each sampling. The nine samples (n=9) consisted of three samples taken on each of three different days.

Table 1. Particulate Lead Levels From Total M16 Emissions

Ammunition	Mean (mg Pb/filter, n=9)	s.d.
Standard Round	1.60	0.47
Plastic Round	0.43	0.07
.22 Round	0.20	0.05

Table 2 shows the results in mg/filter of sampling breech lead emissions. Nine rounds were fired and one filter was used for each sample. The nine samples (n=9) consisted of three samples taken on each of three different days.

Table 2. Particulate Lead Levels From Breech M16 Emissions

Ammunition	Mean (mg Pb/filter, n=9)	s.d.
Standard Round	0.22	0.08
Plastic Round	0.03	0.01
.22 Round	0.06	0.01

In the case of breech samples, nine rounds were used for a single sample in order to obtain lead levels within our detection limits. Since the M16 rifle's chamber remains open after the last round is fired, we used nine rounds (rather than all ten available from the magazine) to avoid drawing muzzle emissions back through the barrel and into our samples.

In firing multiple rounds in this manner, we encountered many instances of jamming when we used the .22 caliber subcaliber device. This problem was also encountered to a lesser extent when we used the XM2 5.56 mm automatic weapon practice bolt for the plastic rounds. Both bolts, especially the one for firing .22 rounds, seemed to function best when they were thoroughly cleaned and oiled.

We analyzed the data with the Statistical Analysis System for Personal Computer (SAS Institute, Inc., Cary, NC). When we compared the mean values for emissions from the three types of rounds, we concluded that the standard round is statistically different from both the .22 and the plastic rounds, but that the .22 and plastic rounds are not statistically different from each other. This was true for both the total emissions and the breech emissions, and can be attributed both to the scatter of the data and to the overlap of ranges of the sample analyses for .22 and plastic rounds.

However, when we used the same computer software to process only data for the .22 and plastic rounds, comparisons of the mean indicated that the .22 and the plastic rounds were statistically different from one another. These statistical results also held true for both the total emissions sampling and the breech emissions.

By observing the filters visually after sampling (Figure 2), one may estimate total particulates. Comparison of total emissions (1 round per sample) to breech emissions (9 rounds per sample) indicated that substantially more particulate matter is released from total emissions. As between the plastic and .22 rounds, more particulates seem to be released by the plastic round in both total and breech emissions. This contrasts with our finding of more particulate lead for .22 rounds than for plastic rounds when we considered only breech emissions. The additional particulate matter from the plastic rounds can be attributed to their larger casings, which contain more powder and therefore would be expected to release greater quantities of particulate combustion products such as polynuclear aromatic hydrocarbons (PAHs) and airborne metals other than lead.[8] Data for total emissions (Table 1), indicate that twice as much particulate lead is released by the plastic round as by the .22 round. Therefore, without proper ventilation systems, use of the plastic round will not reduce airborne particulate lead levels. However, the data do indicate (Table 2) that twice as much particulate lead is released in breech emissions by the .22 round as by the plastic round. If a ventilation system were designed to effectively remove muzzle emissions from the firing line, use of plastic rounds could greatly reduce the exposure of firing personnel to particulate lead.

A correlation between the particulate lead emitted and the amount contained in the cartridge could not be done because complete information on the contents of the plastic round was not available.

CONCLUSIONS

Of the three types of ammunition considered in this study, the standard round releases the most airborne particulate lead from both the muzzle and the breech of the M16 rifle. The plastic round produces less airborne particulate lead than the .22 round for breech emissions. However, the plastic round produces more airborne particulate lead than the .22 round for total (breech plus muzzle) emissions.

If a range ventilation system were designed with a strong enough air flow from the firing line toward the target area, it would remove essentially all of the muzzle emissions from the vicinity of firing personnel. In this case, using plastic rounds could greatly reduce exposure of personnel to airborne particulate lead. However, if such a ventilation system is not feasible or is ineffective, using the .22 rounds would result in lower exposure levels to airborne particulate lead. Therefore, the quality of ventilation in a firing range can determine which type of practice ammunition will result in the least amount of exposure to particulate lead.

In addition to particulate lead, there are many other combustion products from small caliber weapons that could pose health hazards.[8] The test housing used in this study has the capability of collecting all particulate, gaseous, and aerosol emissions and it could be used to evaluate exposure levels to these potentially hazardous combustion products and therefore provide more accurate assessment of related health hazards.

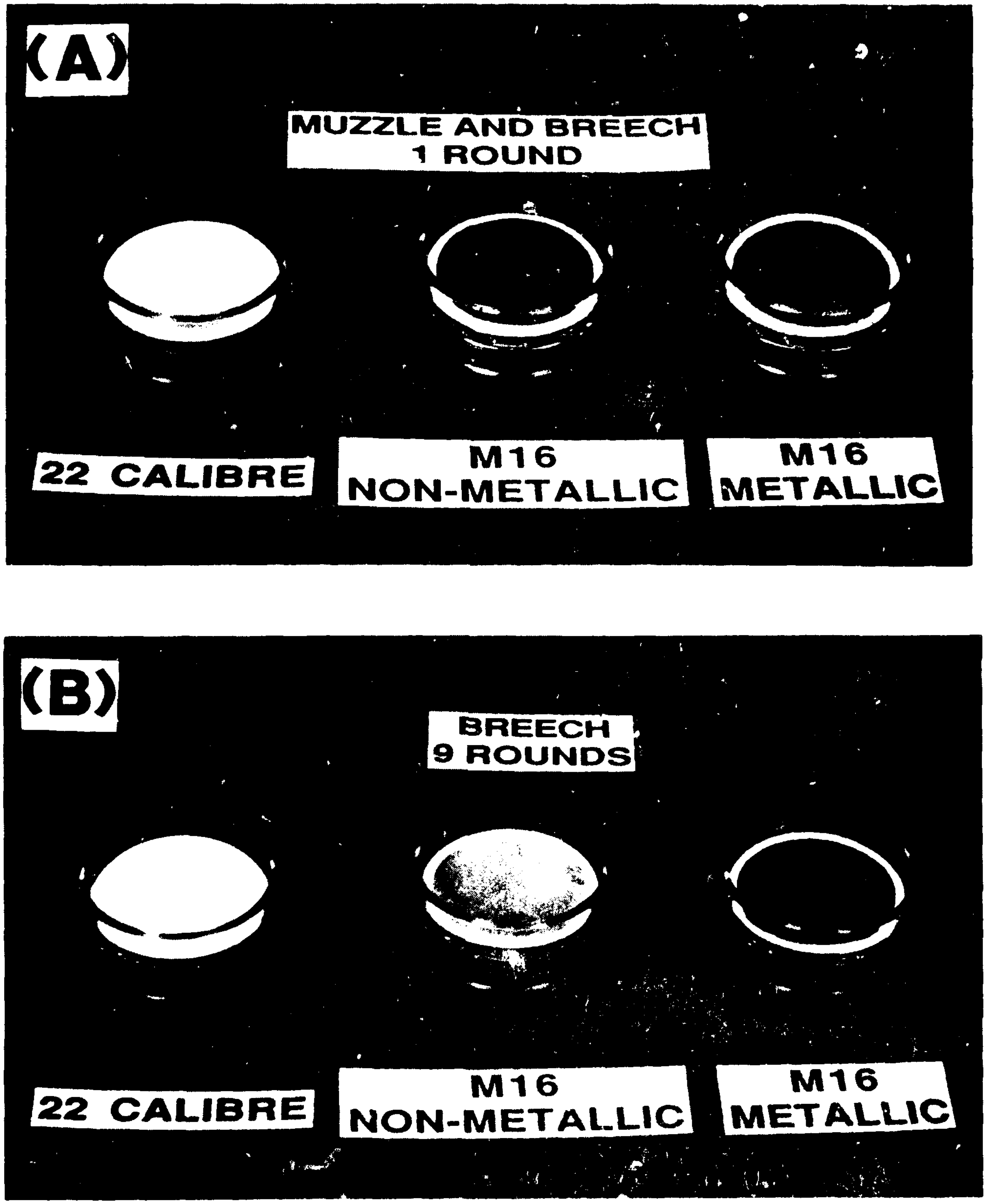

FIG. 2. TOTAL COLLECTED PARTICULATES ON CEM FILTERS FROM FIRING M16 WITHIN TEST HOUSING:

(A) TOTAL PARTICULATE EMISSIONS;

(B) BREECH PARTICULATE EMISSIONS

With the described experimental procedure, it would also be possible to evaluate combustion products of newly developed propellant systems rapidly and accurately and to anticipate health hazards and exposure levels before they become a large-scale problem.

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LITERATURE CITED

1. Personal Communication, 3 February 1988, LTC James Schmittendorf, NGB-AVN-S, National Guard Bureau, Aberdeen Proving Ground, MD.

2. Goyer, R.A. 1986. Toxic effects of metals. In: C.D. Klassen, M.O. Amdur, and J. Doull, eds. Casarett and Doull's Toxicology - The Basic Science of Poisons, 3rd ed. Pp. 582-635. MacMillan Publishing Company, New York, NY.

3. Landrigan, P. J., A. S. McKinney, L. C. Hopkins, W. W. Rhodes, W. A. Price, and D.H. Cox. 1975. Chronic lead absorption; result of poor ventilation in an indoor pistol range. JAMA: 234(4), pp. 394-397.

4. Fischbein, A., C. Rice, L. Sarkozi, S.H. Kon, M. Petrocci, I. J. Selikoff. 1979. Exposure to lead in firing ranges. JAMA: 241(11), pp. 1141-1144.

5. Letter, National Guard Bureau, NGB-AVN-S, 27 March 1987, subject: Health Hazard Assessment of Plastic Ammuition.

6. Perkin-Elmer. Analytical Methods for Atomic Absorption Spectrophotometer. 197 .

7. N SH Manual of Analytical Methods, 2nd ed., V. 1, P&CAM 102, U.S. D partment of Health, Education, and Welfare, Publ. (NIOSH) 77-157-A. 1 77.

8. Snelson, A., P. Ase, W. Bock, and R. Butler, 1983, Characterization of Combustion Products from Military Propellants, Final Report, Contract No. DAMD 17-80-C-0019, U.S. Army Bioengineering Research and Development Laboratory, Fort Detrick, Frederick, MD 21701-5010.

Appendix A

Dilution Formula and Chart

DILUTION FORMULA FOR FLUSHING HOUSING WITH NITROGEN

$$\% \text{ Remaining in housing} = [e^{(T(-F/V))}]100$$

Where: T = Elapsed time of flushing, min.
F = Flow rate of flushing, L/min.
V = Volume of housing, L
e = natural log, 2.71828

DILUTION TABLES

System volume of 133 liters (total emissions sampling - both sections of housing)

PERCENT LEFT IN SYSTEM

time	Flow rate (liters/min)					
	61.00	63.00	65.00*	67.00	69.00	71.00
0	100.0	100.0	100.0	100.0	100.0	100.0
1	63.2	62.3	61.3	60.4	59.5	58.6
2	40.0	38.8	37.6	36.5	35.4	34.4
3	25.3	24.1	23.1	22.1	21.1	20.2
4	16.0	15.0	14.2	13.3	12.6	11.8
5	10.1	9.4	8.7	8.1	7.5	6.9
6	6.4	5.8	5.3	4.9	4.4	4.1
7	4.0	3.6	3.3	2.9	2.6	2.4
8	2.5	2.3	2.0	1.8	1.6	1.4
9	1.6	1.4	1.2	1.1	0.9	0.8
10*	1.0	0.9	0.8	0.6	0.6	0.5
11	0.6	0.5	0.5	0.4	0.3	0.3
12	0.4	0.3	0.3	0.2	0.2	0.2
13	0.3	0.2	0.2	0.1	0.1	0.1
14	0.2	0.1	0.1	0.1	0.1	0.1
15	0.1	0.1	0.1	0.1	0.0	0.0

System volume of 66.5 liters (breech emissions sampling - one section of housing)

PERCENT LEFT IN SYSTEM

time	Flow rate (liters/min)					
	61.00	63.00	65.00*	67.00	69.00	71.00
0	100.0	100.0	100.0	100.0	100.0	100.0
1	40.0	38.8	37.6	36.5	35.4	34.4
2	16.0	15.0	14.2	13.3	12.6	11.8
3	6.4	5.8	5.3	4.9	4.4	4.1
4	2.5	2.3	2.0	1.8	1.6	1.4
5*	1.0	0.9	0.8	0.6	0.6	0.5
6	0.4	0.3	0.3	0.2	0.2	0.2
7	0.2	0.1	0.1	0.1	0.1	0.1
8	0.1	0.1	0.0	0.0	0.0	0.0

* - Indicates flow rates and flushing times used in this study.

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